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Running head: DISINHIBITION, IMPULSIVITY, AND AUTONOMIC ACTIVITY

Disinhibited Behaviors in Young Children: Relations With Impulsivity and Autonomic  
Psychophysiology

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### Abstract

Cardiac activity has long been considered as a psychophysiological marker of adaptive psychological adjustment. Irregularities in autonomic nervous system activity have long been implicated in both externalizing and disinhibitory behaviors. The present study used a battery of assessments in children ages 4.5-5.5 years to examine the relation among disinhibitory measures. Additionally, cardiovascular activity and reactivity was examined. Mothers rated impulsivity and internalizing/externalizing behaviors. Reward-dominance and passive-avoidance response inhibition (i.e., via errors of commission) tasks were included. Results showed that behaviorally uninhibited children began with an attenuated sympathetic response (i.e., lengthened pre-ejection period) to an interview with a novel experimenter, while inhibited children began with a high level of sympathetic activity. Further, behavioral impulsivity was related to low sympathetic activity at rest. Consistent with theories of disinhibition, externalizing behaviors and measures of behavioral impulsivity were related to a reward-dominant response style. Findings are discussed with regard to motivational theories of behavior.

**Keywords:** Respiratory sinus arrhythmia; Pre-ejection period; Temperament; Impulsivity; Externalizing behaviors.

Behavioral inhibition is a temperamental quality one can see in children as they learn to interact with their expanding social environment. In interacting with the environment, a child can be characterized as shy or sociable, introverted or extraverted, fearful of novel stimuli and adults or engaging with novelty, and generally timid or outgoing. These pairs of classifications describe behaviorally inhibited and behaviorally uninhibited people, respectively. Children may exhibit extremes of inhibition, reflecting different possible future pathologies. Extremely inhibited children may be at risk for future psychopathologies (such as anxiety disorders) and health effects (Kagan, Reznick, & Snidman, 1987; Rubin, Stewart, & Coplan, 1995). Uninhibited children may be at risk for externalizing disorders (Rothbart, Posner, & Hershey, 1995) and problematic social and moral interactions (Chen, Chen, Li, & Wang, 2009). Although a child that is uninhibited may not experience psychopathology, a combination of risk factors could predispose a child to such an outcome. Two sub-domains of a greater construct are behavioral inhibition and behavioral impulsivity, and these may be predicted to produce similar outcomes, behaviorally or physiologically. Indeed, Rothbart et al. (1995) linked the absence of extraverted behaviors (e.g., impulsivity) combined with the presence of behavioral inhibition (i.e., fear) to the prevention of future psychopathology, such as externalizing behaviors.

The research reported here explores topics that have rarely been integrated in developmental research, with the aim of finding common correlates to disinhibited behaviors in young children prior to entry to school. Thus, the topic of behavioral inhibition and impulsivity as possible sub-domains of disinhibition explained by similar motivational tendencies and autonomic indices will be explored here. One branch of characteristics that has been associated with early onset of externalizing psychopathologies is the lack of behavior control underpinned by physiological substrates such as autonomic nervous system irregularities.

### **Autonomic Nervous System Irregularities and Disinhibited Behaviors**

The autonomic nervous system is classically divided into two subsystems: the parasympathetic nervous system (PNS) and the sympathetic nervous system (SNS). Sympathetic and parasympathetic divisions are sometimes viewed as functioning in "opposition" to each other; sympathetic activity increases heart rate, while parasympathetic activity decreases heart rate. However, studies that consider each branch of the autonomic nervous system independently are limited since each system does not operate independently. Rather, it is the case that multiple physiological systems are in a perpetual process of coordinated fine-tuning to meet individual and environmental demands (Bauer, et al., 2002). Of importance to the present study, under conditions of chronic intense stress in which stress response systems are excessively activated, physiological systems may become dysregulated, thereby contributing to the behavioral precursors of externalizing (Bauer, Quas, & Boyce, 2002) as well as internalizing disorders.

#### **SNS Activation**

The SNS is activated in response to stress, enabling the body for a fight-or-flight response by increasing heart rate and oxygen flow throughout the body (Boucsein, 1992). However substantial individual differences characterize SNS activation (Fowles, Kochanska, & Murray, 2000).

Low SNS activation seems to be linked with externalizing disorders. Across a systematic series of empirical investigations low baseline heart rate (which has usually been assumed to reflect an underaroused SNS) has been documented in school-aged children, adolescent and adult samples with externalizing problems (see Ortiz & Raine, 2004). Most importantly low resting heart rate in late childhood has been found to be predictive of criminality in adulthood (Raine, Reynolds, Venables, & Mednick, 1997). It has been postulated that low SNS arousal may be a genetic precursor for aggressive behavior (Raine,

Venables, & Williams, 1990). If this postulation has grounds, then one might expect to find low SNS in younger children who may be showing signs of early behavior problems. Indeed, Beauchaine and colleagues utilizing a more direct indicator of SNS activation, the cardiac pre-ejection period (PEP), have documented attenuated levels of SNS activation (i.e., lengthened cardiac PEP) both at baseline as well as during reward conditions in adolescents, but also importantly preschoolers with clinical levels of conduct problems (Beauchaine, Gatzke-Kopp, & Mead, 2007). PEP is an estimate of the time between the electrical initiation of the heart beat and the time that blood is ejected into the aorta (Sherwood, et al., 1990). A short time between the electrical signal and the ejection of blood is taken as greater SNS activity. Pre-ejection period has been found to be a reasonable marker of sympathetic activity in laboratory conditions in children (Quigley & Stifter, 2006).

Several theoretical accounts have been proposed to explain the association between low SNS arousal and externalizing problems. The stimulation-seeking theory (see Eysenck & Gudjonsson, 1989) argues that the common biological condition underlying serious patterns of conduct problems involves the inheritance of a nervous system which is relatively insensitive to low levels of stimulation. It is argued that individuals with such a physiotype, will be extraverted, impulsive, and sensation seeking because under conditions of relatively low stimulation they find themselves at a suboptimal level of arousal which is aversive. To increase their arousal, many will participate in high-risk activities.

In terms of linking patterns of disinhibited behaviors, Kagan et al. (1984) found that 4-year-olds who were rated as extremely behaviorally uninhibited at 21 months had lower and less stable heart rates (indicative of higher variability in heart rates) during two baselines and during cognitive tasks than their inhibited counterparts. Similar results were found when the children were assessed 18 months later (Reznick, Kagan, Snidman, Gerste, Baak, & Rosenberg, 1986). Kagan, Reznick, and Snidman (1988) also reported a moderate correlation

between behavioral inhibition and urinary norepinephrine levels (reflecting primarily peripheral norepinephrine activity). Norepinephrine is a primary neurotransmitter of the sympathetic nervous system (Kagan et al., 1988). Because behaviorally uninhibited children are less fearful in novel situations, they may show less sympathetic activity at rest than inhibited children. However, the links between behavioral inhibition and PEP have not been very strong in prior research (Buss, Davidson, Kalin, & Goldsmith, 2004; Buss, Goldsmith, & Davidson, 2005; Talge, Donzella, & Gunnar, 2008), although a few do support an association between low fearfulness and longer PEP values, indicating low sympathetic arousal (Buss, et al., 2004; Buss, et al., 2005). It may be that this branch of the autonomic nervous system is not as responsive in young children (Quigley & Stifter, 2006).

### **PNS Activation**

Vagal tone is considered to reflect the level of activity in the PNS as indexed by respiratory sinus arrhythmia (RSA) or cyclic increases and decreases in heart rate during respiration (Katona & Jih, 1975). Because vagal outflow is inhibitory, increases in vagal efference during exhalation result into heart rate deceleration; decreases in vagal efference during inhalation results into heart rate acceleration. This happens because excitatory sympathetic influences operate relatively unrestricted during periods of vagal withdrawal, which is explained by Porges's polyvagal theory (Porges, 2003). The phylogenetically newer branch, the *smart vagus* which mediates RSA is found only in mammals, and evolved under the need to vigorously regulate the increased metabolic output. This includes modulation of fight/flight responding that serves social interaction. Engagement in social interaction requires sustained attention, which is accompanied by vagally mediated heart rate deceleration (Suess, Porges, & Plude, 1994). In contrast, fighting and fleeing are characterized by anger and panic, respectively, which are associated with vagal withdrawal resulting in heart rate acceleration (Porges, 1995; Porges, 2003). This facilitates large

increases in cardiac output by the sympathetic nervous system (SNS), which is no longer opposed by inhibitory vagal influences. Thus, the smart vagus inhibits acceleratory SNS input to the heart when attention and/or social engagement are adaptive, and withdraws this inhibitory effect when fighting or fleeing are adaptive. Thus, the polyvagal theory predicts that emotion regulation and social affiliation are an outcome of the regulatory functions of the smart vagus. Consistent with this notion, high resting RSA has been linked to appropriate emotional reactivity (Stifter & Fox, 1990), children's social engagement (Fox & Field, 1989), social competence (Eisenberg, Fabes, Murphy, Maszk, Smith, & Karbon, 1995), and enhanced attentional ability (Suess, et al., 1994). Several studies have linked high RSA in newborns with positive developmental outcomes, suggesting that high RSA is an important physiological marker of appropriate engagement with the environment (Hofheimer, Wood, Porges, Pearson, & Lawson, 1995). In contrast children with low RSA have been considered at risk because they may have difficulty attending and reacting to environmental stimuli (Porges, 1991; Wilson & Gottman, 1996). Consistent with this notion, decreased RSA tone has been reported for antisocial children and adolescents (Beauchaine, Katkin, Strassberg, & Snarr, 2001, Mezzacappa, Tremblay, Kindlon, et al 1997), as well as for trait hostile adults (Sloan, Shapiro, Bigger, Bagiella, Steinman, & Gorman, 1994).

Beyond resting RSA, a dimension of PNS activation that would be important to consider in the context of externalizing psychopathologies is vagal reactivity in response to challenge. In other words, this RSA reactivity measure indicates the extent of decrease (suppression) in RSA during situations where coping or emotional and behavioral regulation is required. While low resting RSA has been reported to be strongly intertwined to diminished capacity for suppression of RSA to meet environmental demands, they may be differentially related to temperamental reactivity and regulation (Calkins, 1997; Huffman, Bryan, del Carmen, Pedersen, Doussard-Roosevelt, & Porges, 1998). Suppression of RSA



during demanding tasks has been considered to reflect physiological processes that allow the child to shift focus from internal homeostatic demands to demands that require internal processing or the generation of coping strategies to control arousal. Thus, suppression of RSA is considered to be a physiological mechanism that mediates sustained attention and behaviors indicative of active coping that are mediated by the parasympathetic nervous system (Porges, 1996; Wilson & Gottman, 1996). Suppression of RSA during challenging situations has been reported to be related to better regulation, greater self-soothing and attentional control in infancy (DeGangi, DiPietro, Porges, & Greenspan, 1991; Huffman et al., 1998), fewer behavior problems and more appropriate emotion regulation in preschoolers (Calkins, 1997; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996; Calkins & Dedmon, 2000), and sustained attention in school-age children (Suess et al., 1994). On the other hand escalated RSA reactivity to various challenges has been observed in temperamentally shy (i.e., behaviorally inhibited) and angrily reactive children (Donzella, Gunnar, Krueger, & Alwin, 2000). Additionally, social behavior may elicit changes in autonomic activity that depends on shorter time intervals of reactivity. For example, although the findings only indicated a trend toward significance, Schmidt, Fox, Schulkin, and Gold (1999) found that uninhibited 7-year-olds preparing to give a speech decreased parasympathetic activity and subsequently increased it during the following minute of the task. Temperamentally inhibited children continually decreased parasympathetic activity during the entire duration of the task. Consequently, it is plausible that while the ability to suppress RSA is related to complex responses involving the regulation of attention and social behavior, a deficit in this ability is implicated in early display of behavior problems (Porges, 1996).

While autonomic irregularities are well documented across empirical investigations these irregularities have not been systematically seen in the context of a comprehensive theoretical framework. One such theoretical framework is Gray's Motivational Theory.

### **Gray's Motivational Theory, SNS activity and Motivational Tendencies**

Gray's Motivational Theory (1970) elaborated further by Fowles (1980) is one of the very first theoretical frameworks that attempted to explain disinhibited behaviors with reference to the behavior activation system (BAS)<sup>1</sup> and behavior inhibition system (BIS). On the basis of Gray's theoretical framework, when BAS is activated it governs behavior towards reward. This system is mediated by dopaminergic pathways including the ventral tegmental area and the nucleus accumbens of the ventral striatum. These neural structures are infused with dopamine following appetitive behaviors, resulting in pleasant affective state (Nader, Bechara & Van der Kooy, 1997). It has been suggested that low central dopamine activity may lead affected individuals to seek larger and larger rewards to achieve the reinforcing levels of pleasure (Laakso, Wallius, Kajander, Bergman Eskola & Solin, 2003).

In contrast to the BAS, the BIS is activated when conflict occurs between competing motivational goals (e.g. the classic approach-avoidance conflict). The BIS inhibits appetitive responding when aversive consequences are anticipated. BIS activation results in arousal and experience of anxiety, which in turn causes inhibition of ongoing behaviors and the initiation of information processing for resolution of the conflict (Wallace, Malterer & Newman, 2009). An under-responsive BIS has been linked to disorders of disinhibition while an over-responsive BIS has been linked to internalizing disorders (Beauchaine, 2001). Under this account, behavior disinhibition occurs because punishment cues do not elicit anxiety which in turn would inhibit appetite responding when competing reward contingencies are present.

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<sup>1</sup> In his early writings Gray(1970) used the term reward system to refer to behavior activation system. Gray subsequently (see Gray 1987 a) adopted the term behavioral activation system coined by Fowles (1980). In more recent writings Gray (see Gray & McNaughton, 1996) suggested that the term *behavioral approach system* be used.

When it comes to BAS, the argument becomes more speculative since the evidence is indirect. Overresponsiveness to reward for instance has been considered to be indicative of an atypically heightened BAS. That is, several researchers have postulated heightened BAS (Fowles, 1980) as the likely neural substrate for the excessive reward-seeking behaviors characteristic of externalizing psychopathology (Beauchaine, 2001; Beauchaine, Katkin, Strassberg, & Snarr, 2001; Cloninger, Svrakic, & Svrakic, 1997; Quay, 1988).

### **The Present Study**

Impulsivity is evident in “syndromes of disinhibition” proposed by Newman (1987). These syndromes include psychopathological disorders such as psychopathy and externalizing behaviors as well as impulsivity. Impulsivity is believed to be characterized by a strong approach motivation to rewards in one’s environment (Newman, 1987). This response style which is evident in laboratory tasks has been labeled “reward dominance” (Newman & Kosson, 1986). In one study, 3- to 5-year-old uninhibited children showed heightened physiological arousal when playing a memory game involving prearranged winning and losing streaks, compared with inhibited children (Donzella, Gunnar, Krueger, & Alwin, 2000). Thus, uninhibited children also appear to be highly motivated to obtain rewards and to experience high arousal in their pursuit. The large number of passive avoidance errors in groups with uninhibited temperaments indicates the high value placed upon potential rewards by these populations, whereby they often fail to inhibit their responses to punished items. However, White et al. (1994) proposed multiple facets to the construct of impulsivity, such that cognitive impulsivity reflects a lack of planful and effortful cognitive performance, particularly when shifting mental attention. Behavioral manifestations of impulsivity such as motor restlessness or impatience/impersistence represent the other type of impulsivity (behavioral impulsivity; White et al., 1994). Behavioral inhibition may be related more to measures of behavioral impulsivity than to measures of cognitive impulsivity.

Indeed, behaviorally uninhibited 4-year-olds were more likely to show restlessness in the laboratory than inhibited children (Kagan et al., 1984).

The goal of the present study was to examine behavioral inhibition and two types of impulsivity, and their relationship to each other and to cardiovascular function in a general population of pre-school children. There are a number of reasons for focusing on this preschool period. First, the personality constructs being examined are assumed to be relatively stable and apparent early in life (Reznick, et al., 1986). For example, Kagan, Reznick, Snidman, Gibbons and Johnson (1988) found that temperamental styles were relatively stable in children who were assessed continually from the age of 21 months to 5 ½ years. Second, in the years before a child enters school they are learning to inhibit and control their own behavior, often with less parental guidance over time (Livesey & Morgan, 1991). Third, the preschool years are important also because adult antisociality can be linked with behaviors seen in childhood (Robins, 1966).

In the present study, we used a multi-level approach, such that measures included a multisource, multimethod battery of impulsivity, as was done in White et al. (1994). We also used measures of uninhibited behaviors, externalizing symptoms, and cardiovascular psychophysiology. Our goal was to (a) assess the relation between impulsivity measures and other forms of disinhibited behaviors such as a lack of inhibition in novel social interactions, and externalizing symptoms; and (b) examine the link between cardiovascular psychophysiology and disinhibited behaviors inclusive of lack of inhibition in novel social interactions and externalizing symptoms. The primary prediction of the present study is that behavioral inhibition would be more related to measures of behavioral impulsivity than to measures of cognitive impulsivity.

Kagan et al. (1984) found that uninhibited children had lower heart rates than inhibited children, and we will investigate this possibility in our normative sample of

children. However, we used heart period, which is the inverse of heart rate, because heart period has a more linear relationship than heart rate with underlying autonomic changes that mediate short-term cardiac changes (Berntson, Cacioppo, & Quigley, 1995). Thus, we expect longer heart periods for more strongly uninhibited children. In general, we expect more strongly disinhibited participants to show higher basal parasympathetic activity (higher RSA) and lower basal sympathetic activity (longer PEP) than the more strongly inhibited participants.

Phasic physiological activity will be measured during an interview with a novel experimenter and during a passive-avoidance task, in which children must control their responding to go and no-go stimuli. Individuals with high parasympathetic activity (i.e., high RSA) typically suppress RSA to appropriately attend to their environment. Those who do not suppress RSA may be dysregulated with their environment (Porges et al., 1994). Thus, a normal response for activities requiring attentional processing (such as speaking with a novel experimenter or playing a challenging computer game), is a decrease in RSA reactivity (Beauchaine, Gatzke-Kopp, & Mead, 2007). We expect children who show more behavioral uninhibited behaviors to have an exaggerated increase in parasympathetic activity or to fail to suppress parasympathetic activity, thereby failing to consider environmental cues in guiding their approach response. In contrast, we expect the more strongly behaviorally uninhibited children to show less sympathetic activity (i.e., longer PEP) to speaking with a novel experimenter. We will also examine the response of behaviorally inhibited and uninhibited children to the social situation minute by minute (Schmitt et al.). An expected average response to the passive-avoidance task would be an increase in sympathetic activity and an accompanying decrease in parasympathetic activity. Presumably, those children who are more engaged and who seem to care more about winning would show an enhanced sympathetic response (Donzella, et al., 2000). Thus, more strongly disinhibited participants

are predicted to have an exaggerated increase in sympathetic activity (i.e., a shortening of PEP) than their less strongly disinhibited counterparts.

## **Method**

### **Participants**

Participants were 38 Caucasian preschool children (16 girls and 22 boys) between the ages of 4 ½ to 5 ½ years ( $M = 62.8$ ,  $SD = 3.3$  months) from the community of a small Northeastern city in the USA. They were recruited as part of a longitudinal study of children's socio-emotional behavior and physiology. Ninety-two percent of the parents who gave consent were either married or remarried and 18% of the children lived with a divorced parent. 61% lived in households where the parent(s) income was reported between \$50,000 and \$99,999 annually, 21% comprised those with incomes between \$35,000 and \$49,999, 7.9% comprised those with incomes between \$15,000 and \$34,999, and 7.9% comprised those with incomes between \$100,000 and \$199,999. Only one family reported an income between \$0 and \$15,000. The average length of parent education was 14.18 years ( $SD = 1.35$ ). Thus, most families were in the middle-class to upper middle-class range with more than a high school education.

### **Measures**

**Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997).** To ensure that verbal ability did not covary with performance on any of the tasks, we administered the PPVT to all participants. The PPVT is a brief norm-referenced measure of verbal ability for those aged 2.5 to 90 years. This test assesses a child's receptive language abilities. The standardized scores of the third revision of the PPVT correlated .90 with the Full-Scale IQ scores from the Wechsler Intelligence Scale for Children, Third Revision in a sample of 41 children aged 7 years, 11 months through 14 years, 4 months (Dunn & Dunn, 1997). The correlation with Verbal Scale IQ was slightly higher than the

correlation with Performance Scale IQ (.91 and .82, respectively).

**Response inhibition tasks measuring errors of commission.**

*Passive avoidance computer task.* This task was modified from Newman and Kosson's (1986) research with psychopaths, where impulsive psychopaths commit more errors of commission than nonpsychopaths when rewards and punishments are both possible outcomes. A simple go/no-go task was used to assess passive-avoidance performance. Six black and white drawings of animals were presented via a computer monitor for varying amounts of time (decreasing from 1200ms to 600ms for the last set of 9 stimuli). Each set of nine stimuli consisted of four rabbits (the target animal) and five distracter animals (an elephant, a frog, a buck, a kangaroo, and a polar bear). The interval between one stimulus offset and the onset of the succeeding stimulus was 100ms during which the computer monitor displayed a fixation point in the center of the screen. Participants were asked to press a key as soon the rabbit (the go stimulus) was presented, but not to press any key when other animals were presented. The picture disappeared from the screen either in response to a key press or when the presentation time elapsed. Tones signaled the accuracy of a response, and the computer recorded the number of errors of commission or false-alarms (i.e., pressing the key to any other animal than the rabbit), which were submitted to a log transformation to normalize the variable.

*Reward/punishment and punishment only go/no-go tasks.* This task was modified from Newman and Kosson's (1986) research with psychopaths, and indicated the ability to withhold responding in the face of rewards and punishers, but were not different from nonpsychopaths when only punishers were used. For this task, treats were given and removed to reward and penalize correct and incorrect responses. Two sets of four animal pictures were used (a dog, cat, pig, and bee or a cow, duck, sheep, and owl) to create sets of 20 pictures to be randomly administered to the participant. Each set was randomly ordered

with the constraint that go or no-go stimuli could not occupy three consecutive slots. Each picture was presented for 1500 ms on a computer screen. Participants responded to the go stimuli (two randomly chosen pictures) by making the sound of the animal before time expired. In between, the experimenter rewarded or penalized the participant by giving or taking a treat and then pressed a key to continue to the next stimulus. Before beginning, the experimenter asked the participant to make the sounds of all the animals. Any that were not known were demonstrated and the participant repeated the sound. The experimenter then verified that the participant understood the task, by asking the child what they are to do when presented with each of the animal pictures. There were two tasks that the participants completed, one with one set of animals and one with the other set of animals; the two tasks were counterbalanced for order. For the task with rewards and punishers, participants began with five M&Ms or Pepperidge Farm cheddar Goldfish crackers and the examiner rewarded the participants with another one when they vocalized the sound of the animal. The examiner took one away when the participant had a false-alarm, so they responded to a no-go item. For the punishment-only task, the participants began with 10 treats and the examiner took a treat away when the participant had a false-alarm.

### **Cognitive impulsivity.**

***Circle-drawing task.*** This task was modified from the circle-tracing task used by Bachorowski and Newman (1990) with extroverted and introverted adults, and was designed to assess cognitive impulsivity, such that the extroverted individual has difficulty delaying tracing to the end of a circle. White et al. (1994) found that children who completed the task more quickly showed more cognitive impulsivity, which was related to delinquency at age 10 and 13. In the circle-drawing task, the child used a crayon to follow a circular path, created from two concentric circles, on a sheet of paper, and the task was completed twice. In both cases, the child was asked to draw a circle, staying within the circular track on the paper and



beginning and ending at a defined point: the beginning was marked with a green arrow, the end with a red stop sign. In the first version of the task, the child was asked to simply draw a circle using the start and end points given. The second time, the child was asked to draw the circle again as slowly as possible. Consistent with Bachorowski and Newman (1990) and White et al. (1994), the time taken to move from the starting point to the ending point was measured for both versions of the task and the difference between the two times taken as the dependent measure. After removing two outliers who were more than three standard deviations from the mean at the top part of the range, the circle drawing times were submitted to a square root transformation to normalize the variable for accurate interpretation of correlations. Also, the variable was reversed so that greater values indicate faster completion times with the slow instructions. Thus, the measure indexed greater impulsivity with greater values.

***Card-playing task.*** This was a revised version of the card-playing task originally designed by Newman et al. (1987) to test reward dominance, where people may be hypersensitive to rewards in the presence of punishment cues. A modified version of this task has been used with adolescents (O'Brien & Frick, 1996) and children (White et al., 1994), which has distinguished between children with disinhibited problem behavior from other problem behaviors and has significantly predicted delinquency at age 10. Twenty-five cards (8.5 x 11 inches) were prepared, each displaying two identical, complex, computer-produced drawings. Participants were first given five edible treats (i.e., M&M's or goldfish crackers) and asked to say whether the two pictures on each card were the same or different. Participants were prompted for a response if none was given within 4 seconds. The participant received one treat for a rewarded response and lost one treat for a punished response. The cards were presented to the child in a prearranged order of reward and punishment, thus rewards and punishers were non-contingent on the participants' responses.

The rewards and punishments were divided into five blocks of 5 cards: the first block of five cards contained four reward cards and one punishment card; the second block of five cards contained three reward and two punishment cards. Each subsequent block of 5 contained an additional punishment card. The final block of five contained all punishment cards.

Participants were told that they could stop the task at any time. Participants were prompted after the second punishment card with the question, “Would you like to play again or would you like to stop?” The number of cards voluntarily played by the participant was recorded.

A greater number of cards played would indicate a greater level of reward dominance. Given the skewness of this measure, the variable was transformed using a log transformation.

### **Behavioral impulsivity.**

***Children’s Behavior Questionnaire.*** The CBQ is a caregiver report measure, which is designed to provide an assessment of temperament in children. Individual differences are assessed on 15 primary temperament characteristics: Positive Anticipation, Smiling/ Laughter, High Intensity Pleasure, Activity Level, Impulsivity; Shyness, Discomfort, Fear, Anger/ Frustration, Sadness, Soothability, Inhibitory Control, Attentional Focusing, Low Intensity Pleasure, and Perceptual Sensitivity. Factor analyses of the CBQ scales identified three broad dimensions of temperament: Extraversion/ Surgency, Negative Affectivity, and Effortful Control (Rothbart, Ahadi, Hersey & Fisher, 2001). Six items from the entire CBQ were chosen for the present study to measure parent-rated impulsivity. The items from the CBQ consisted of 1) usually rushes into an activity without thinking about it; 2) when practicing an activity, has a hard time keeping her/his mind on it; 3) will move from one task to another without completing any of them; 4) usually stops and thinks things over before deciding to do something; 5) has difficulty waiting in line for something; 6) when s/he sees a toy or game s/he wants, is eager to have it right then. These six items were combined with three items from the CBCL to measure

maternal-rated impulsivity, because they were found to predict delinquency in a child cohort (White et al., 1994): 1) can't concentrate, can't pay attention for long; 2) can't sit still, restless, or hyperactive; and 3) impulsive or acts without thinking.

***Observer-rated impulsivity.*** Impatience/impersistence and motor restlessness were coded from behaviors and comments made by the child during relevant segments using the coding guidelines of Lynam et al. (1991). White et al. (1994) found impatience/impersistence to be related to other measures of behavioral impulsivity, and significantly predicted delinquency at age 13. The segments of the video to be coded were ones where the child would most likely evidence the behaviors of interest here. Ratings were made for every 3 minutes of the 12-minute Wizard of Oz video. The warm-up computer game and the PPVT were longer than 12 minutes and were coded (using a 4-point scale) for 5-minute blocks of the task. Leftover blocks of time that were shorter than 5 minutes but longer than 1 minute were also coded to ensure completeness of data. Impatience was coded from behaviors meant to shorten the duration of the testing session, such as asking to stop, complaining about time, reaching for the materials, or making mistakes without care. Motor restlessness was indicated by physical movements inferred to be an expression of physical energy. The amount of movement, such as repetitive behaviors, tugging or picking at clothes or body, handling materials roughly, and fidgeting, was coded. If present, the behaviors were further coded as slight, mild, moderate, or strong using a 4-point scale: a slight presence (1), a mild presence (2), a moderate presence (3), and a strong presence (4). Separate scores for motor restlessness and impatience were obtained.

Fifteen percent of the videos (total of 6) were coded by two separate coders to test for inter-rater reliability. After successful training, one coder coded all of the videos. Fisher's intraclass correlation coefficients were computed for motor restlessness ( $ICC =$

.78) and impatience ( $ICC = .77$ ). Intraclass correlations were used because they are considered more conservative than percent agreement or zero-order correlations for observations (Hunter & Koopman, 1990). For both variables, scores were summed across tasks and an average score per minute was derived. These scores were submitted to a log transformation.

**Assessment of Inhibition.** An interview immediately followed a presentation of some scenes from the Wizard of Oz. The interview was done by a novel experimenter. During the interview, the child answered questions about the content of the video and emotions evoked by the clips presented. Interviewers used a standard script, which asked participants to indicate how the scenes in the video made them feel. This was done using a pictorial emotional rating scale so children could understand and answer (by pointing instead of talking if they wished) the interviewer questions more easily. The interviewer asked about the content of the video to ensure participants had watched and understood the video. All participants recalled specific content indicating they attended to the video.

Child behavioral inhibition was coded during a warm-up computer game, the PPVT, and the child interview, such that each involved interacting with a novel experimenter. The coding procedures were similar to prior research with children (Kagan, Reznick, & Gibbons, 1989; Reznick, et al., 1986). In particular, five behaviors were coded: 1) the latency to leave the parent when entering the lab; 2) the percentage of time the child was within the parent's reach was coded during the warm-up computer game (Kagan, et al., 1989); 3) the latency to point to the pictorial rating scale when prompted during the child interview; 4) the proportion of questions answered during the child interview was coded (Kagan, et al., 1989; Reznick, et al., 1986); 5) and the number of spontaneous or extraneous utterances during two tasks.

Fifteen percent of the videos (total of 6) were coded separately by two research

assistants, to test for inter-rater reliability. All six variables were dichotomized, each by visual inspection of their distribution, given their skewed distributions: this corresponded to a 75<sup>th</sup> percentile split. These items were then averaged to create the measure of uninhibited social behaviors, and the Cronbach's alpha for this scale was .70. In order for high scores to indicate stronger uninhibited behaviors, the latency to leave, the percentage of time within the parent's reach, and the latency to point to the rating scale were reverse coded.

**Externalizing and Internalizing Symptoms.** The Child Behavior Checklist (CBCL; Achenbach, 1991) is an empirically based parent report checklist used to classify children's problems. Factor analyses of ratings have consistently isolated two broad factors called Internalizing and Externalizing. These broad factors are reflected in narrow bands (factors), such as Anxious/Depressed, Somatic Complaints, and Social Withdrawal that comprise the Internalizing score. Aggression and Delinquency narrow bands comprise the Externalizing score (Achenbach, 1991). In the present study, the externalizing scale was used, as well as the internalizing scale. Because few fathers completed the questionnaires, only maternal ratings were used.

**Physiological Measures.** The electrocardiogram (ECG) and impedance cardiogram (ZCG) were recorded using disposable Ag-AgCl spot electrodes. Pediatric spot electrodes were used to maximize participant compliance and comfort. In addition, spot electrodes provide reliable measures of pre-ejection (PEP) period, which was the main dependent variable, assessed using impedance cardiography in the current study (Boomsma, De Vries, & Orlebeke, 1989). Four electrodes were placed: one approximately behind cervical vertebrae, C<sub>4</sub>; one on the upper part of the sternum between the clavicles; one over the xiphisternal junction on the chest; and one over the thoracic vertebrae at approximately T<sub>6</sub>. These electrode placements ensured that the electrodes on the back were at least 3 cm above

and below, respectively, the two electrodes on the chest (Qu, Zhang, Webster, & Tompkins, 1986). The electrocardiogram was recorded via two electrodes placed in a modified Lead II configuration over the distal right collarbone and lower left rib.

The ECG and ZCG were recorded using a Minnesota Impedance Cardiograph (Model 304B) connected to a laptop computer equipped with an A/D converter and data acquisition software. Sampling for ECG and  $dZ/dt$  was set at 1000Hz and  $Z_0$  was sampled at 500Hz, with ECG and  $dZ/dt$  signals later decimated to 500 Hz for data processing. Impedance-derived measures were reduced offline and ensemble-averaged following visual inspection of the impedance cardiographic waveforms and computer-aided event detection. The interbeat interval files were edited and analyzed using ANS Suites software (Department of Psychology, Ohio State University). Editing the files consisted of scanning the data for outlier points with respect to adjacent data and interpolating to retain the interbeat interval time series. Less than 1% of the data required interpolation. One-minute means were derived from the ensemble-averaged ECG and  $dZ/dt$  waveforms. We calculated heart period (HP), which is the time between successive beats, because HP has a more linear relationship with underlying autonomic changes that mediate short-term cardiac changes than heart rate (Berntson, Cacioppo, & Quigley, 1995).

PEP was calculated as the time between the onset of the Q wave of the ECG and the B point of the  $dZ/dt$  waveform (i.e., beginning of ejection). Indeed, PEP is a measure of the changes in sympathetic effects on inotropic (contractility) function, rather than chronotropic (rate) function. However, using similar methods to the present study, task-induced changes in PEP have been shown in a previous study to be related to sympathetically mediated changes in heart period in adults (Berntson et al., 1994).

Respiratory sinus arrhythmia (RSA) was derived using the data from the ECG

following the method of Porges and Bohrer (MXEdit, ver.2.21, Delta Biometrics, Inc.) for each minute of HP data. Respiratory rate and relative depth was derived from the impedance signal using methods described elsewhere (Ernst, Litvack, Lozano, Cacioppo, & Berntson, 1999).

### **Procedure**

Prior to the study, parents were mailed two copies each of the CBCL (Achenbach, 1991) and the CBQ (Ahadi, Rothbart, & Ye, 1993). The parent who accompanied the child to the experimental session (typically the mother) was asked to bring the completed CBCL and CBQ questionnaires. Parental informed consent was completed, and the CBCL and CBQ were retrieved from both parents where available. Upon entering the testing room, the child was invited by a novel experimenter to play a warm-up computer game. While the child was playing the warm-up computer game, another experimenter acquired written informed consent from the parent, obtained demographic data, and collected the CBCL and the CBQ, which were usually completed prior to the visit.

With the parent nearby, the principal experimenter placed four impedance electrodes and two electrocardiogram electrodes on the child. Stickers were offered to encourage compliance with the electrode placement procedures. Then, the participant was seated on a wooden chair at a child-size wooden table. During a 10-minute electrode stabilization period, the participant completed the first version of the circle-drawing task with no instructions on speed of completion. The Peabody Picture Vocabulary Test –Third Edition (PPVT; Dunn & Dunn, 1997) was also administered during the stabilization period, using the instructions for young children (Dunn & Dunn, 1997).

Next, a video of selected scenes from “The Wizard of Oz” was shown to the child for 12 minutes while the experimenter was out of the room. The last minute of the video (Dorothy’s reunion scene) was used as a “vanilla baseline,” since it was rated by independent

ratings as low in intensity prior to the present study, and it directly preceded the tasks of interest. Following the video, a novel experimenter approached the child to perform the child interview. The principal experimenter returned to move a computer in front of the participant to administer the passive avoidance task, placing the keyboard on the table for the participant to use. After this, there was a cold pressor task and a hand-grip task, which were part of another study (Quigley & Stifter, 2006). The participant was given more stickers for cooperating with the removal of the electrodes.

The participant was again seated and the second version of the circle-drawing task was completed with the instructions to draw slowly. Finally, the card-playing task was completed. In total, the sessions took about 1 ½ hours to complete. The participant and his or her parent were thanked and compensated \$10 for their participation. All procedures were videotaped for later coding of observational data.

### **Missing Data**

One participant refused to cooperate with the placing of electrodes. Thus, cardiovascular data on 37 participants were available. In addition, another participant's impedance cardiography data for the entire session could not be scored due to electrical interference. Moreover, one participant had no usable impedance cardiography data for the interview, and three participants had no usable impedance cardiography data for the passive-avoidance task due to movement and electrical interference.

### **Data Analysis**

The shortest interview duration was 3.5 minutes. Thus, the first three minutes of the interview were averaged where available to obtain HP, RSA and PEP. In addition, if there were an effect of a novel experimenter on physiological responses to the interview, this would be expected to be maximal during the initial part of the interview. HP, RSA and PEP were averaged over the 2 minutes of the passive avoidance computer task.



**Creation of impulsivity scales.** Table 1 lists the descriptive statistics for the main study variables, using the non-transformed values for ease of interpretation. To examine the relations among the impulsivity measures, we performed zero-order correlations and these are shown in Table 2. Observed impatience was significantly related to observed motor restlessness ( $r(38) = .36, p < .05$ ), as predicted. However, consistent with other research (e.g., White et al., 1994), maternal ratings of impulsivity were not correlated with impatience/impersistence and motor restlessness. We decided to combine the three items for several reasons. Children are often required to sit still and follow instruction in a classroom or in a testing setting. In the home, the child is usually not required to sit still and engage in structured play. Hence, behaviors observed in the laboratory, which is a novel place to most preschool-aged children, will be very different from those observed in the child's home. Combining ratings allows for the assessment of behaviors across various domains, which may provide greater predictability if one allows for the behavior to be coded as present whether it is observed in one setting or another (Kamphaus & Frick, 2002). Consistent with White et al., the two cognitive impulsivity items (i.e., circle drawing task and card playing task) were combined.

## Results

### Relations Among Demographic Measures and Dependent Measures

The zero-order correlations among the study's measures and the demographic measures were examined first. Age in months was significantly related to performance on the circle drawing task ( $r(36) = .42, p < .05$ ). Older children drew more slowly when slow instructions were given. However, older children were more restless during the session ( $r(38) = .33, p < .05$ ). Income was negatively related to maternal ratings of impulsivity ( $r(36) = -.35, p < .05$ ). None of the other measures were related to verbal ability, gender, age, income or educational level.

### **The Relation of Impulsivity Measures to Other Disinhibition Measures**

We first examined the relation between the two composite variables – cognitive and behavioral impulsivity – with uninhibited temperament and externalizing and internalizing symptoms. The zero-order correlations are shown in Table 3. Although there was a slightly stronger relation between an uninhibited temperament and behavioral impulsivity than with cognitive impulsivity, the correlation was nonsignificant. The same was true for externalizing symptoms and behavioral impulsivity but again was nonsignificant.

When looking at the correlation between behavioral and cognitive impulsivity and the tasks where errors of commission could be made, only behavioral impulsivity was related to commission errors on the reward/punishment go/no-go task ( $r(38) = .37, p < .05$ ). As predicted, the number of commission errors on the reward/punishment go/no-go task was positively related to externalizing symptoms. Of importance, the number of commission errors when only a punisher was used was not significantly related to externalizing symptoms. Thus, it appears that children highest in externalizing symptoms committed a greater number of commission errors when rewards and punishers competed for attention in the go/no-go task. The commission errors on the computerized passive avoidance task were positively related to maternal-rated internalizing symptoms, but not externalizing symptoms. Participants who were higher in internalizing committed more errors of commission on the computer game, which was a timed task. Maternal-rated externalizing scores were significantly related to maternal-rated impulsivity, which may be elevated because both scales were created using the CBCL and because they share method variance.

### **Validity of Psychophysiological Reactivity**

Repeated-measures ANOVAs were performed to investigate changes in children's HP, RSA, and PEP over time. Tests of within-subjects showed that HP differed significantly across tasks ( $F(2, 70) = 46.97, p < .05$ ). Effect sizes were computed as partial Eta squared

values. The effect of the tasks accounted for 57% of the variability in HP. Planned contrasts showed that HP was significantly different between baseline and interview and between baseline and the computer task ( $F(1, 35) = 24.36, p < .05$ , partial  $\eta^2 = .41$  and  $F(1, 35) = 21.91, p < .05$ , partial  $\eta^2 = .39$ , respectively). HP shortened for the interview task and lengthened for the computer task. Thus, heart rate increased to the interview and decreased to the passive avoidance computer task.

RSA also differed across tasks ( $F(2, 70) = 29.72, p < .05$ ). The effect of the tasks accounted for 46% of the variability in RSA. Planned contrasts showed that RSA was significantly different between baseline and interview and between baseline and the computer task ( $F(1, 35) = 24.80, p < .05$ , partial  $\eta^2 = .42$  and  $F(1, 35) = 4.66, p < .05$ , partial  $\eta^2 = .12$ , respectively). RSA decreased for the interview task and increased for the computer task. Thus, there was RSA suppression in response to the interview and an increase in RSA, indicating heightened PNS activity to the computer task.

The sphericity assumption with PEP was not met so the Greenhouse-Geisser correction was applied (Mauchly's  $W = .76, X^2 = 8.25, p < .05$ ). PEP differed significantly across tasks ( $F(1.61, 49.98) = 3.69, p < .05$ ). The effect of the various tasks accounted for 11% of the variability in PEP. Planned contrasts with PEP showed no significant differences for the interview and the computer task ( $F(1, 31) = .00, p = \text{n.s.}$ , partial  $\eta^2 = .00$  and  $F(1, 31) = 3.74, p = .06$ , partial  $\eta^2 = .11$ , respectively). Although the effect was modest and nonsignificant, PEP shortened during the computer task. In sum, there was a non-significant increase in SNS activity along with a significant increase in PNS activity to the passive avoidance computer task. This would suggest a concomitant increase that is akin to putting on the 'brake' and the 'gas' at the same time.

Additionally, the responses were consistent across the task. The intertask consistency was investigated using intraclass correlations, given the need to look at consistency within

individuals. The intertask consistency was high for HP and RSA ( $ICC(36) = .66, p < .001$ ;  $ICC(36) = .64, p < .001$ , respectively), and this was particularly evident for PEP ( $ICC(32) = .97, p < .001$ ). Thus, PEP in particular does not discriminate and responds similarly within individuals to the two tasks.

### **Psychophysiological Reactivity and Disinhibited Behaviors**

Zero-order correlations were performed between the baseline psychophysiological indices with an uninhibited temperament, behavioral and cognitive impulsivity, and externalizing symptoms, although uninhibited temperament was unrelated to externalizing symptoms ( $r(33) = .03, p = ns$ ). As expected, a positive and significant correlation between an uninhibited temperament and baseline HP was found ( $r(36) = .36, p < .05$ ). Specifically, highly uninhibited children showed longer baseline heart periods (i.e., lower heart rates). No relation between externalizing and baseline physiological activity was found. Behavioral impulsivity was positively related to baseline PEP, indicating that greater behavioral impulsivity was marked by less sympathetic arousal at rest given the longer PEP values ( $r(34) = .41, p < .05$ ).

For the interview, the most extreme responses would be expected to be elicited in the first minute of the introduction to the stranger. Thus, a repeated-measures ANOVA with the psychophysiological indices for baseline and the three minutes of the interview as the within-subjects factor and the median split of behavioral inhibition as the between-subjects factor. Uninhibited and inhibited children differed with respect to PEP during baseline and the 3 minutes immediately following (i.e., during the interview;  $F(3,96) = 2.98, p < .05$ ). The effect of these two activities for the two groups accounted for 9% of the variability in PEP. The contrasts indicated that there was a difference in PEP across the groups from the first minute (inhibited:  $M = 73.54, SD = 6.75$ ; uninhibited:  $M = 74.72, SD = 9.00$ ) to the second minute (inhibited:  $M = 74.72, SD = 6.38$ ; uninhibited:  $M = 73.70, SD = 8.96$ ;  $F(1,32) = 9.10$ ,

$p < .05$ ) of the interview. This interaction effect accounted for 22% of the variability in PEP. However, there was no significant interaction across groups from baseline to the first minute of the interview ( $F(1,32) = 0.48, p = \text{n.s.}, \text{partial } \eta^2 = .02$ ) or from the second minute of the interview to the third ( $F(1,32) = 0.18, p = \text{n.s.}, \text{partial } \eta^2 = .01$ ).

Thus, the effect of the change from baseline to the interview occurred after the first minute of interaction with the stranger. As illustrated in Figure 1, inhibited children started with shorter values of PEP and remained so when first meeting the novel person. However, during the following minute, inhibited children lengthened PEP. Uninhibited children began with longer values of PEP and remained so during the first minute of the interview. During the second minute, they shortened PEP. Both groups shortened PEP during the last minute, though the inhibited group remained more reserved. The analyses with HP and RSA were nonsignificant.

Using partial correlations and controlling for baseline measures, no relations were found with psychophysiological reactivity to the passive avoidance task.

### Discussion

Consistent with predictions and prior research (Kagan, et al., 1984), highly uninhibited children showed longer heart periods (lower heart rates). The consistency with prior research lends support to the validity of our findings. However, we were able to extend our findings beyond those of prior studies by including an interaction with a stranger and by including multiple measures of disinhibition. Contrary to the initial hypothesis, behavioral inhibition was neither linked to behavioral impulsivity nor to cognitive impulsivity.

Reactivity during a social interaction with a stranger was expected to differ for children with different temperaments. Children who were highly uninhibited were expected to have lower sympathetic nervous system (SNS) reactivity to social novelty (Talge, et al., 2008). Post-hoc tests revealed that from the profiles of PEP reactivity shown for inhibited

and uninhibited children, it appears that uninhibited children began with low SNS arousal and relaxed or oriented more during the first minute. During the second minute, they seemed to have engaged with the examiner, as evidenced by their increase in SNS activity. Inhibited children began at a high level of SNS arousal and remained high when first meeting the novel person. However, during the following minute, inhibited children relaxed as evidenced by their decreased SNS activity. Both groups increased SNS activity during the minute when they were most likely speaking to the examiner; however, the inhibited group remained a little more reserved. Admittedly, this explanation is post-hoc; however, the results are consistent with Kagan's (1988) assertion that inhibited children have higher levels of stress hormones that are released by sympathetic activation. Thus, it seems that children with observable and codifiable differences in their emotional responses to social novelty also differed in psychophysiological reactivity to the exact social situation to which they should show distinct responses.

The pattern of physiological responses seems to suggest that the presence of a novel person conducting the interview was perceived as nonthreatening to most of the participants, such that no changes in PEP were evident. This may be because the parent was in the room when the unfamiliar adult entered. Moreover, participants generally suppressed RSA during the interview, which could indicate attention to socially relevant stimuli that may be mediated by the parasympathetic nervous system (Porges, 1991, 1996; Wilson & Gottman, 1996).

The pattern of physiological responses to the passive avoidance task, suggests that the participants had, in general, concentrated their efforts on their performance in the task. The experimenter emphasized speed and accuracy in the performance of the task for all participants, which seemed to have resulted in a coactivation of both branches of the autonomic nervous system. A coactivation of both the sympathetic and parasympathetic branches may occur in response to challenge, such that the optimal or most adaptive

behavioral responses are more ambiguous in these environments than in familiar ones (Berntson et al., 1997). Therefore, the pattern of physiological responses observed in the present study is consistent with the participants showing an active engagement with the passive-avoidance task. However, the nonsignificant increase in PEP may indicate a more non-responsive SNS at this young age as compared to older people (Quigley & Stifter, 2006; Talge et al., 2008). For example, Buss et al. (2004) found no differences in PEP, despite differences in heart rate and RSA in a group of toddlers. Additionally, children 3-8 years old showed little change in PEP to a series of stressor tasks (Alkon et al., 2003). However, it seems by age 8 to 10, children may be able to launch their SNS activation (Allen & Matthews, 1997; Matthews et al., 2002; see Quigley & Stifter, 2006).

Uninhibited children were expected to show greater parasympathetic reactivity than inhibited children. Contrary to predictions, the analyses with baseline and phasic RSA revealed no significant differences. Consistent with the increase in arousal shown when engaging in a competitive game for rewards (Donzella et al., 2000), a highly uninhibited style was expected to be related to shorter PEP while playing the computer game. However, PEP did not differ when playing the passive avoidance computer game. Since no difference was found on the computer task performance for inhibited and uninhibited individuals, it is possible that the game was not found to be rewarding. Indeed, because the game was programmed to proceed quickly on the computer, we could not time any rewards and punishments to coincide with performance. Thus, only an auditory signal was played when the participants were successful and unsuccessful.

The relations among impulsivity and measures of errors of commission were important, given the dearth of research attempting to discriminate measures of inhibition and reward/punishment tasks. White et al. (1994) had not included any tasks that measured errors of commission. The present study found the further the child continued on the card-playing

task despite further losses the greater behavioral impulsivity (i.e., impatience/impersistence) was evinced. This relation could be an early indicator of behavior problems, where a reward-dominant style is combined with hyperactivity (Fowles & Dindo, 2009). Drawing heavily upon the theoretical framework of Gray's motivational model combined with Porges's polyvagal theory of emotion regulation, Beauchaine (2001) proposed an integrative model of autonomic nervous system activity underpinning emotional and behavioral predispositions. According to this integrative model, Gray's motivational model as reflected in BAS and BIS falls under SNS control. He further argued that both fight and flight behaviors are mediated peripherally by the SNS, and that theories of appetitive and aversive motivation such as Gray's motivational model need to be considered together in order to account for the predominant response set (approach vs. avoidance) that characterizes varied forms of psychopathology (Beauchaine, 2001). Consistent with attenuated levels of PEP (i.e., lengthened PEP), which Beauchaine et al. (2007) documented in preschoolers with clinical levels of conduct problems, we found attenuated levels of PEP associated with behavioral impulsivity. Indeed, Beauchaine's (2001) integrative model predicts heightened BAS for appetitive behavior tendencies of aggression and impulsivity which are considered to be the behavioral manifestations of disinhibition. Beauchaine (2001) further argued that an under-responsive central reward system resulting in a chronically frustrated mood state, coupled with deficient vagal modulation of emotion, leads to the sensation-seeking and aggressive behaviors of conduct disorder. However, externalizing symptoms, in the present study, were not related to any of the physiological measures in the present study.

A general lack of reflection in tasks involving rewards and punishments has also been considered in children with conduct disorder (CD; Newman et al., 1987; O'Brien & Frick, 1996). Because there is a lack of reflection after a punishment in impulsive people, possibly due to a poorly functioning BIS, it has been proposed that their behavior is more dependent



on rewards than on punishments. Children with higher externalizing symptoms and children who were rated as more impulsive by their mothers showed poor response modulation when incentives (i.e., snacks) were used to reward responses during a reward/punishment go/no-go task. Thus, these disinhibited behaviors were associated with a strong approach motivation when rewards were paired with punishers. Arnett, Smith and Newman (1997) suggest that rewards are sought by the impulsive person with little delay. This is especially true when a response set for reward has been established (Arnett, et al., 1997; Newman, et al., 1987), which was what set the reward/punishment task apart from the punishment-only task.

O'Brien and Frick (1996) also measured reward dominance clinic-referred and comparison-control children 6 to 13 years old using a card-playing task. Although O'Brien and Frick (1996) reported that the number of trials played did not relate to the child's impulsivity, we found that the number of trials played on the card-playing task was related to observed impatience/impersistence during the lab session. Since O'Brien and Frick only used parent-reports of impulsivity, this could explain why our results are different. Further research is needed to understand the link between tasks that purport to measure cognitive impulsivity and those that measure behavioral impulsivity. White et al. (1994) also conceded that the measures, which comprised what they named behavioral impulsivity, were all observer-rated and may have formed behavioral impulsivity due to their shared variances. In the present study, the two observational measures (i.e., impatience/impersistence and motor restlessness) correlated highly. However, the behavioral impulsivity measures were correlated with two tasks that measure reward dominance (i.e., reward/punishment go/no-go and card playing task). Future studies into behavioral impulsivity could look into the role of reward dominance tasks in this construct.

We were not able to show that maternal-rated behavioral impulsivity correlated with the observer-rated measures of behavioral impulsivity in the laboratory. White et al. (1994)

also found that their measure of parent-rated undercontrol did not correlate highly (highest correlation found was .22) with observer-rated impulsivity. In the present study, maternal-rated impulsivity was obtained by questionnaire, which assessed behavior exhibited by the child in his or her typical environment. In the home, the child is usually not required to sit still and engage in structured play. Hence, behaviors observed in the laboratory, which could be a novel place to most preschool-aged children, will be very different from those observed in the child's home. Children in school encounter similar structured activities as in the laboratory, thus creating more consistent ratings of behavior between teacher and observer when children enter school. It is, therefore, important for researchers to include as many sources as possible in rating behaviors.

A surprising finding was shown with one of the impulsivity measures. Although the circle drawing time under slow instructions was unrelated to externalizing symptoms, it was related to internalizing symptoms; children who had more internalizing symptoms drew more slowly. Bachorowski and Newman (1990) found that participants who scored high on introversion and neuroticism completed the circle tracing slower than did participants who scored high on extraversion and on neuroticism. In fact, an introverted personality and greater internalizing symptoms are each characterized by high levels of anxiety. This is the first known study to show this is true for young children.

Our findings should be interpreted cautiously based on several limitations. First, the sample size was small and comprised mainly of Caucasians from middle to upper-middle class families. Therefore, the generalizability of the results is limited. Indeed, future research should attempt to clarify the role of autonomic activity and reactivity in inhibited and uninhibited groups from disadvantaged backgrounds (Krenichyn, Saegert, & Evans, 2001), particularly with regard to temperament. Second, the present study assessed autonomic activity in the laboratory only. Zahn and Kruesi (1993) suggested that the

autonomic activity and behavior link may be dependent upon the situational or social contexts in which they were observed. For example, behavioral measures may be more strongly related to autonomic measures when obtained in the same environment. Third, in the present study, children were not selected based on a display of extremes in temperament; therefore these children may be quite average in temperament. Thus, the extreme ends of the scale may be important in predicting future psychopathology. Future research should investigate the cognitive and behavioral factors that influence continuity in child temperament, and whether these changes in temperament also change the risk for psychopathology.

The present study is unique in that both branches of the autonomic nervous system that innervate a single organ were measured. In prior research, the role of the sympathetic branch of the peripheral nervous system had been difficult to ascertain when each branch was measured separately. The present pattern of results as regards impulsivity and behavioral inhibition indicate the necessity for simultaneous assessment of both autonomic branches for conclusions about the relationships between autonomic functioning and externalizing as well as internalizing psychopathologies characterized by disinhibition. Also, the present study is one of a few studies (White, et al., 1994) to examine the relations among impulsivity and other disinhibition measures. Our study builds on White et al.'s (1994) results by showing these relations in younger children and with a cohort of both boys and girls. With the present study's small sample size, it was not determinable whether behavioral inhibition and behavioral impulsivity were separable constructs. A small and nonsignificant correlation was found, which could signify that they are measures of a larger construct. The fact that they are not strongly related may mean they are sub-domains of an encompassing construct. Two measures of a domain are not typically highly interrelated, especially if the measures assess

risk of the development of psychopathology. Indeed, the combination of the two could indicate a risk for psychopathology (Rothbart et al., 1995).

The present study has implications for the development of externalizing behaviors. An uninhibited style was related to lower heart rate levels and to low initial reactivity when engaging in a social interaction with a stranger. It has been suggested that a behavioral uninhibited style may predispose children to fail to receive the parents' message and, as a result, may be at risk for a cold interpersonal style lacking an empathetic response. For example, fearless children more often than fearful children developed a conscience at a later age (Kochanska, 1993). However, successful development of conscience was achieved for both fearful and fearless children with different parenting techniques tailored for each. Kochanska's (1993) findings demonstrate that temperament can organize the development of conscience, but it is neither a necessary nor a fixed influence (see Marshall, Fox, & Henderson, 2000). Of particular importance to the present study, inhibitory control (e.g., self-control) contributed to the development of conscience (Kochanska, Murray, & Coy, 1997).

In conclusion, children who are very outgoing and extraverted seem to show a distinct physiological response to situations that tap their outgoing nature, such as interacting with a stranger. However, this socially outgoing behavior is not highly related to being restless, trying to move ahead in activities rapidly, interrupting people, and being impatient when engaging in structured tasks. Instead, being restless and impatient was related to an orientation toward gaining rewards without weighing the possible loss that could result. This is consistent with an overactive BAS or underactive BIS, such that being restless and impatient was associated with a low level of sympathetic arousal which may make these restless and impatient children take risks. Thus, including measures of disinhibitory behaviors in young children may be useful in predicting risk for psychopathology.

## References

- Achenbach, T. M. (1991). *Manual for the Child Behavior Checklist/4-18 and 1991 Profile*. Burlington, VT: Department of Psychiatry, University of Vermont.
- Ahadi, S. A., Rothbart, M., & Ye, R. (1993). Children's temperament in the U.S. and China: Similarities and differences. *European Journal of Personality*, 7, 359-377.
- Allen, M. T., & Mathews, K. A. (1997) Hemodynamic Responses to Laboratory Stressors in Children and Adolescents: The Influences of Age, Race and Gender. *Psychophysiology*, 34, 329 – 339.
- Alkon, A., Ramler, M., & MacLennan, K. (2003) Evaluation of Mental Health Consultation in Child Care Center. *Early Childhood Education Journal*, 31(2), 91 – 99.
- Arnett, P. A., Smith S. S., & Newman, J. P. (1997) Approach and Avoidance Motivation in Incarcerated Psychopaths during Passive Avoidance. *Journal of Personality and Social Psychology*, 72, 1413 – 1428.
- Bachorowski, J. A., & Newman, J. P. (1990). Impulsive motor behavior: Effects of personality and goal salience. *Journal of Personality and Social Psychology*, 58(3), 512-518.
- Bauer, A. M., Quas, J. A., & Boyce, W. T. (2002). Associations between physiological reactivity and children's behavior: Advantages of a multisystem approach. *Journal of Developmental and Behavioral Pediatrics*, 23(2), 102-113.
- Beauchaine, T.P., 2001. Vagal tone, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. *Development and Psychopathology*, 13, 183–214.
- Beauchaine, T., Gatzke-Kopp, L., & Mead, H. K. (2007). Polyvagal Theory and developmental psychopathology: Emotion dysregulation and conduct problems from preschool to adolescence. *Biological Psychology*, 74, 174-184.

- Beauchaine, T. P., Katkin, E. S., Strassberg, Z., & Snarr, J. (2001). Disinhibitory psychopathology in male adolescents: Discriminating conduct disorder from attention-deficit/hyperactivity disorder through concurrent assessment of multiple autonomic states. *Journal of Abnormal Psychology, 110*(4), 610-624.
- Berntson, G. G., Bigger, J. T., Eckberg, D. L. et al. (1997). Heart Rate Variability: Origins, Methods, and Interpretive Caveats. *Psychophysiology, 34*, 623 – 648.
- Berntson, G. G., Cacioppo, J. T., Binkley, P. F., Uchino, B. N., Quigley, K. S., & Fieldstone, A. (1994). Autonomic Cardiac Control: III. Psychological Stress and Cardiac Responses in Autonomic Space as revealed by Pharmacological Blockades. *Psychophysiology, 31*, 599 – 608.
- Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1995). The metrics of cardiac chronotropism: Biometric perspectives. *Psychophysiology, 32*, 162–171.
- Boomsma, D. I., De Vries, J., & Orlebeke, J. F. (1989). Comparison of spot and band impedance cardiogram electrodes across different tasks. *Psychophysiology, 26*(6), 695-699.
- Boucsein, W. (1992). *Electrodermal activity*. New York: Plenum Pub Corp.
- Buss, K. A., Davidson, R. J., Kalin, N. H., & Goldsmith, H. H. (2004). Context-specific freezing and associated physiological reactivity as a dysregulated fear response. *Developmental Psychology, 40*(4), 583-593.
- Buss, K. A., Goldsmith, H. H., & Davidson, R. J. (2005). Cardiac reactivity is associated with changes in negative emotion in 24-month-olds. *Developmental Psychobiology, 46*(2), 118-132. doi:10.1002/dev.20048.
- Calkins, S. D. (1997). Cardiac vagal tone indices of temperamental reactivity and behavioral regulation in young children. *Developmental Psychobiology, 31*, 125-135.

- Calkins, S.D. & Dedmon, S.A. (2000). Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. *Journal of Abnormal Child Psychology*, 28, 103-118.
- Chen, X., Chen, H., Li, D., & Wang, L. (2009). Early childhood behavioral inhibition and social and school adjustment in Chinese children: A 5-year longitudinal study. *Child Development* 80, 1692-1704.
- Cloninger C. R., Svrakic N. M. & Svrakic D., (1997) Role of Personality self-organization in development of mental order and disorder. *Development and Psychopathology*, 9(4), 881-906.
- DeGangi, G.A., DiPietro, J.A., Greenspan, S.I., & Porges, S.W. (1991). Psychophysiological characteristics of the regulatory disordered infant. *Infant Behavior and Development*, 14, 37-50.
- Donzella, B., Gunnar, M. R., Krueger, W. K., & Alwin, J. (2000). Cortisol and vagal tone response to competitive challenge in preschoolers: Associations with temperament. *Developmental Psychobiology*, 37, 209–220.
- Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary Test, third edition: Examiner's manual and norms booklet*. Circle Pines, MN: American Guidance Service.
- Eisenberg, N., Fabes, R. A., Murphy, B., Maszk, P., Smith, M., & Karbon, M. (1995). The role of emotionality and regulation in children's social functioning: A longitudinal study. *Child Development*, 66(5), 1360-1384. doi:10.1111/j.1467-8624.1995.tb00940.x.
- Ernst, J. M., Litvack, D. A., Lozano, D. L., Cacioppo, J. T., & Berntson, G. G. (1999) Impedance Pneumography: Noise as Signal in Impedence Cardiography. *Psychophysiology*, 36, 333 – 338.

- Eysenck, H., & Gudjonsson, G. (1989). *The causes and cures of criminality*. New York: Plenum Press.
- Fowles, D.C. (1980). The three arousal model: Implications of Gray's two-factor learning theory for heart rate, electrodermal activity, and psychopathy. *Psychophysiology*, 17, 87–104.
- Fowles, D. C., & Dindo, L. (2009). Temperament and psychopathy: A dual-pathway model. *Current Directions in Psychological Science*, 18(3), 179-183.
- Fowles, D. C., Kochanska, G., & Murray, K. (2000). Electrodermal activity and temperament in preschool children. *Psychophysiology*, 37(6), 777-787. doi:10.1111/1469-8986.3760777.
- Fox, N. A., & Field, T. M. (1989). Individual differences in preschool entry behavior. *Journal of Applied Developmental Psychology*, 10(4), 527-540.
- Hofheimer, J. A., Wood, B. R., Porges, S. W., Pearson, E., & Lawson, E. E. (1995). Respiratory sinus arrhythmia and social interaction patterns in preterm newborns. *Infant Behavior and Development*, 18(2), 233-245. doi: 10.1016/0163-6383(95)90052-7
- Huffman, L. C., Bryan, Y. E., del Carmen, R., Pedersen, F. A., Doussard-Roosevelt, J. A., & Porges, S. W. (1998). Infant Temperament and Cardiac Vagal Tone: Assessments at Twelve Weeks of Age. *Child Development*, 69(3), 624-635. doi:10.1111/j.1467-8624.1998.tb06233.x.
- Hunter, M. A., & Koopman, R. (1990). Interobserver agreement and reliability of infant visual fixation data. *Infant Behavior and Development*, 13, 109-116.
- Kagan, J., Reznick, J. S., Clarke, C., Snidman, N., & Garcia-Coll, C. (1984). Behavioral inhibition to the unfamiliar. *Child Development*, 55, 2212-2225.
- Kagan, J., Reznick, J. S., & Gibbons, J. (1989). Inhibited and uninhibited types of children. *Child Development*, 60, 838-845.



- Kagan, J., Reznick, J. S., & Snidman, N. (1987). The physiology and psychology of behavioral inhibition in children. *Child Development* 58, 1459-1473.
- Kagan, J., Reznick, J. S., & Snidman, N. (1988). Biological bases of childhood shyness. *Science*, 240, 167-171.
- Kamphaus, R. W. & Frick, P. J. (2002) *Clinical Assessment of Child and Adolescent Personality and Behavior (2<sup>nd</sup> Edition)*. Needham Heights, MA: Allyn & Bacon.
- Katona, P. G., & Jih, F. (1975). Respiratory sinus arrhythmia: noninvasive measure of parasympathetic cardiac control. *Journal of Applied Physiology*, 39(5), 801-805.
- Kochanska, G. (1993). Toward a synthesis of parental socialization and child temperament in early development of conscience. *Child Development*, 64, 325-347.
- Kochanska, G., Murray, K., & Coy, K. (1997). Inhibitory control as a contributor to conscience in childhood: From toddler to early school age. *Child Development*, 68, 263-277.
- Krenichyn, K., Saegert, S., & Evans, G. W. (2001). Parents as moderators of psychological and physiological correlates of inner-city children's exposure to violence. *Applied Developmental Psychology*, 22, 581-602.
- Livesey, D. J., & Morgan, G. A. (1991). The development of response inhibition in 4- and 5-year-old children. *Australian Journal of Psychology*, 43(3), 133-137.
- Lynam, D., Moffitt, T. E., White, J. L., & Caspi, A. (1991). *Reliability and validity of videotape-rated impulsivity dimensions (Tech. Rep. No. 1)*. Madison, WI: University of Wisconsin.
- Marshall, P. J., Fox, N. A., & Henderson, H. A. (2000). Temperament as an organizer of development. *Infancy*, 1(2), 239-244.
- Mathews, K. A., Salomon, K., Kenyon, K., & Allen, M. T. (2002) Stability of Children's and Adolescent's hemodynamic Responses to Psychological Challenge: A Three – Year

- Longitudinal Study of a Multiethnic Cohort of Boys and Girls. *Psychophysiology*, 39, 826 – 834.
- Mezzacappa, E., Tremblay, R. E., Kindlon, D., Saul, J. P., Arseneault, L., Seguin, J., et al. (1997). Anxiety, antisocial behavior, and heart rate regulation in adolescent males. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 38 (4), 457-469.
- Nader K., Bechara A. & Van der Kooy D., (1997) Lesions of the lateral parabrachial nucleus block the aversive motivational effects of both morphine and morphine withdrawal but spare morphine's discriminative properties., *Behavioral Neuroscience*, 110(6), 1496-502.
- Newman, J. P., & Kosson, D. S. (1986). Passive avoidance learning in psychopathic and nonpsychopathic offenders. *Journal of Abnormal Psychology*, 95(3), 252-256.
- Newman, J. P., Patterson, C. M., & Kosson, D. S. (1987). Response perseveration in psychopaths. *Journal of Abnormal Psychology*, 96(2), 145-148.
- O'Brien, B. S. & Frick, P. J. (1996) Reward Dominance: Associations with Anxiety, Conduct Problems, and Psychopathy in Children. *Journal of Abnormal Child Psychology*, 24, 223 – 240.
- Ortiz, J., & Raine, A. (2004). Heart rate level and antisocial behavior in children and adolescents: A meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, 43(2), 154-162.
- Porges, S.W. (1991). Vagal mediation of respiratory sinus arrhythmia: Implications for drug delivery. In J.M. Hrushesky, R. Langer and F. Theeuwes (eds.), *Temporal Control of Drug Delivery. Annals of the New York Academy of Sciences*, 618, 57-66.
- Porges, S. W. (1995). Orienting in a defensive world: Mammalian modifications of our evolutionary heritage. A Polyvagal Theory. *Psychophysiology*, 32(4), 301-318.  
doi:10.1111/j.1469-8986.1995.tb01213.x.

- Porges, S. W. (1996). Physiological regulation in high-risk infants: A model for assessment and potential intervention. *Development and Psychopathology*, 8, 43-58.
- Porges, S. W. (2003). The polyvagal theory: phylogenetic contributions to social behavior. *Physiology and Behavior*, 79(3), 503-513.
- Porges, S.W., Doussard-Roosevelt, J.A., Portales, A.L., & Greenspan, S.I. (1996). Infant regulation of the vagal "brake" predicts child behavior problems: A psychobiological model of social behavior. *Developmental Psychobiology*, 29, 697-712.
- Porges, S.W., Doussard-Roosevelt, J.A., Portales, A.L., & Suess, P.E. (1994). Cardiac vagal tone: Stability and relation to difficultness in infants and three-year-old children. *Developmental Psychobiology*, 27, 289-300.
- Quay, H. C. (1988) The Behavioral Reward and Inhibition Systems in Childhood Behavior Disorders. *Attention Deficit Disorder. Volume 3: New research in Attention Treatment and Psychopharmacology*. Oxford, England: Pergamon Press.
- Qu, M., Zhang, Y., Webster, J. G., & Tompkins, W. J. (1986). *IEEE Transactions on Biomedical Engineering*, 33(11), 1029-1035.
- Quigley, K. S., & Stifter, C. A. (2006). A comparative validation of sympathetic reactivity in children and adults. *Psychophysiology*, 43(4), 357-365.
- Laakso A., Wallius E., Kajander J., Bergman J., Eskola O. & Solin O. (2003): Personality traits and striatal dopamine synthesis capacity in healthy subjects. *American Journal of Psychiatry*, 160, 904 –910.
- Raine, A., Reynolds, C., Venables, P. H., & Mednick, S. A. (1997). Biosocial bases of aggressive behavior in childhood. In A. Raine, P. A. Brennan, D. P. Farrington & S. A. Mednick (Eds.), *Biosocial bases of violence* (pp. 1-20). New York: Plenum.

- Raine, A., Venables, P. H., & Williams, M. (1990). Relationships Between Central and Autonomic Measures of Arousal at Age 15 Years and Criminality at Age 24 Years. *Archives of General Psychiatry*, 47(11), 1003-1007.  
doi:10.1001/archpsyc.1990.01810230019003.
- Reznick, J. S., Kagan, J., Snidman, N., Gersten, M., Baak, K., & Rosenberg, A. (1986). Inhibited and uninhibited children: A follow-up study. *Child Development*, 57, 660-680.
- Robins, L. N. (1966) Deviant children grown up. Baltimore: The Williams and Wilkins Co.
- Rothbart, M. K., Posner, M. I., & Hershey, K. L. (1995). Temperament, attention, and developmental psychopathology. In D. Cicchetti & D. J. Cohen (Eds.), *Developmental psychopathology*. New York: John Wiley & Sons.
- Rubin, K. H., Stewart, S. L., & Coplan, R. J. (1995). Social withdrawal in childhood: Conceptual and empirical perspectives. *Advances in Clinical Child Psychology*, 17, 157-196.
- Schmidt, L. A., Fox, N. A., Schulkin, J., & Gold, P. W. (1999). Behavioral and psychophysiological correlates of self presentation in temperamentally shy children. *Developmental Psychobiology*, 35, 119-135.
- Sherwood, A., Allen, M. T., Fahrenberg, J., Kelsey, R. M., Lovallo, W. R., & van Doornen, L. J. P. (1990). Methodological Guidelines for Impedance Cardiography. *Psychophysiology*, 27(1), 1-23. doi:10.1111/j.1469-8986.1990.tb02171.x.
- Sloan, R. P., Shapiro, P. A., Bigger, J. T., Bagiella, E., Steinman, R. C., & Gorman, J. M. (1994). Cardiac autonomic control and hostility in healthy subjects. . *The American Journal of Cardiology*, 74(3), 298-300. doi: DOI: 10.1016/0002-9149(94)90382-4
- Stifter, C. A., & Fox, N. A. (1990). Infant Reactivity: Physiological Correlates of Newborn and 5-Month Temperament.. *Developmental Psychology*, 26(4), 582-588.

- Suess, P. E., Porges, S. W., & Plude, D. J. (1994). Cardiac vagal tone and sustained attention in school-age children. *Psychophysiology*, *31*(1), 17-22. doi:10.1111/j.1469-8986.1994.tb01020.x.
- Talge, N. M., Donzella, B., & Gunnar, M. R. (2008). Fearful temperament and stress reactivity among preschool-aged children. *Infant and Child Development*, *17*(4), 427-445. doi:10.1002/icd.585.
- Wallace, J.F., Malterer, M.B., & Newman, J.P. (2009). Mapping Gray's BIS and BAS Constructs onto Factor 1 and Factor 2 of Hare's Psychopathy Checklist – Revised. *Personality and Individual Differences*, *47*, 812-816.
- Wilson, B.J. & Gottman, J., (1996). Attention – the shuttle between emotion and cognition: Risk, resiliency and physiological bases (pp. 189-228). In E.M. Hetherington and E. Blechman (Eds.), *Stress, coping and resiliency in children and families*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- White, J. L., Moffitt, T. E., Caspi, A., Bartusch, D. J., Needles, D. J., & Stouthamer-Loeber, M. (1994). Measuring impulsivity and examining its relationship to delinquency. *Journal of Abnormal Psychology*, *103*(2), 192-205.
- Zahn, T. P., & Kruesi, M. J. P. (1993). Autonomic activity in boys with disruptive behavior disorders. *Psychophysiology*, *53*, 605-614.

## Research Highlights:

- Reactivity in PEP to a stranger differentiated behaviorally uninhibited and inhibited children
- Like in adults, externalizing and behavioral impulsivity were related to a reward-dominant response style
- Further, behavioral impulsivity was related to low sympathetic activity at rest
- This study shows that disinhibited behaviors can be identified early

Table 1

*Mean Ratings and Performance on Participant-Completed Tasks*

Tasks	M	SD	N
<b>CBCL RATINGS</b>			
Maternal-rated Internalizing	4.45	3.12	33
Maternal-rated Externalizing	9.33	6.43	33
<b>IMPULSIVITY MEASURES</b>			
Card playing task	12.13	6.13	38
Circle drawing task	47.53	45.08	38
Passive Avoidance Task	1.95	2.66	38
Commission errors-Reward/punishment	0.21	0.47	38
Commission errors-Punishment	0.39	0.64	38
Impatience/Impersistence	0.07	0.10	38
Motor restlessness	0.42	0.21	38
Maternal-rated Impulsivity	0.80	0.42	34
<b>UNINHIBITED TEMPERAMENT</b>	0.67	0.27	38
<b>PHYSIOLOGICAL MEASURES</b>			
<b>Heart Period</b>			
Baseline	620.95	54.54	36
Interview	601.04	49.85	37
Passive Avoidance Task	642.07	56.47	37
<b>Respiratory Sinus Arrhythmia</b>			
Baseline	6.34	0.98	36
Interview	5.83	0.95	37
Passive Avoidance Task	6.49	1.05	37
<b>Pre-ejection Period</b>			
Baseline	74.05	7.38	34
Interview	74.21	8.20	35
Passive Avoidance Task	73.01	8.58	33

Table 2

*Intercorrelations Among Impulsivity Measures*

Scale	2	3	4	5	6	7	8
Cognitive Impulsivity							
1. Card playing task	.21	.12	.46**	.30	-.18	.21	-.16
2. Circle drawing task		-.12	.15	-.04	.23	-.13	.09
Behavioral Impulsivity							
3. Maternal Impulsivity			-.01	-.04	.08	.40*	-.36*
4. Impatience/impersistence				.36*	.01	.05	-.09
5. Motor restlessness					-.11	.28	.17
Commission Errors Tasks							
6. Passive Avoidance						-.15	.10
7. Reward/Punishment							.17
8. Punishment Only							-

\* $p < .05$ \*\* $p < .01$



Table 3.

*Correlations among Impulsivity and Other Disinhibited Behaviors.*

Measures	Uninhibited temperament	Internalizing	Externalizing
Card playing task	.06	-.06	.01
Circle drawing task	-.06	-.24	-.23
Cognitive Impulsivity Composite	-.00	-.11	-.03
Maternal Impulsivity	.13	.11	.74***
Impatience/Impersistence	.06	-.40*	-.30
Motor Restlessness	.21	-.15	.00
Behavioral Impulsivity Composite	.26	-.23	.23
Passive Avoidance	-.25	.36*	.03
Commission Errors- Reward/Punishment	.07	.14	.48*
Commission Errors- Punishment Only	.07	.06	-.13

\* $p < .05$ ; \*\*\* $p < .001$

## Figure Captions

*Figure 1.* Plot of the within- and between-subjects interaction between time and temperament in the responding of pre-ejection period (in ms) to the interview with a novel experimenter.

